DRIVERS FOR THE APPLICATION OF AUTOMATION IN CONSTRUCTION ACTIVITIES

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The complex nature of the architectural, engineering and construction industry and increasing demand for innovative and technical construction projects by clients, have resulted in increasing adoption and application of information technology at the design, construction and post-construction phases. One of the current innovative technological method is automation, which has gained popularity in some sectors of the economy like manufacturing, banking and entertainment, among others. To promote the usage of this technique in the construction industry, this study examines a number of success factors for the adoption of automation for various activities and processes involved in execution of construction projects. Using survey method, a close-ended questionnaire was designed around 18 drivers obtained from existing and related literature materials on automation and construction process. The research instrument were thereafter administered to 50 construction professionals including architects, engineers, construction managers, quantity surveyors and construction project managers. Information from the retrieved and completed 40 questionnaires revealed that change in the attitude of construction companies and other stakeholders from traditional way of achieving tasks as well as adequate knowledge and training on automation are the major drivers for the adoption of automation concept in the construction industry. The onus therefore lies on the stakeholders tasked with the obligation to manage, control and regulate construction activities, to continuously organise training and development programmes for construction personnel especially the semi-skilled and skilled. This will increase the level of implementation of automation and other information technology methods in the industry, thereby enhancing personnel productivity and overall performance of construction projects.

Keywords: Automated machine, Construction industry, Project performance, Robotics.

INTRODUCTION

Construction automation is described as an interesting field that focused on applying computer-controlled processes and mechanisation concepts in the construction industry (Ardiny et al., 2015). Basically, in simple terms, it is the use of robotics in the construction industry. Since construction is labour-intensive and the work is done in unsafe/harsh conditions with the scope of work changing frequently, robots in the construction are then used widely to help workers on construction sites (Ellatter, 2008). This can be seen as an advantage/benefit for both the workers and the construction company, because several construction works are seen as hazardous or strenuous to the individuals performing the works (Cottle, 2014).

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Slaughter (1997) stated that dangerous construction works include duties where the workers face the potential of fatal injuries during the performance of these works, these works would include lifting heavy objects, working in uncomfortable positions or labour that is physically exhausting. Construction automation aims to minimise these fatal injuries in the construction industry by using machinery/robotics to do the work (Tambi, et al. 2014; Mistri and Rathod, 2015; Momin, et al. 2015; Ruggiero, et al. 2016). This is due to the fact that changes in building are crucial if the construction world is to improve. Therefore, having appropriate alternative construction methods would help manage the intense rapid growth and need of infrastructure that is needed. There are a lot of benefits of using construction automation; therefore, this research project was designed to examine various drivers of integrating and using construction automation in everyday construction works for all relevant parties involved in the construction industry.

INGREDIENTS FOR AUTOMATION IN CONSTRUCTION

Investigating construction activities which can benefit the most from construction automation could be seen as the first step of implementing automation, as this helps identify which areas can and cannot be automated and in turn makes it easier for it to be tackled. Some aspects are significant and will affect the adaptation of the concept (Balaguer and Abderrahim 2008; Mistri and Rathod, 2015; Momin, et al. 2015), these include:

- Construction companies need to change their attitudes, the industry of machines, centres for research and the government Research and Development officials. This is to develop new high-tech commercial products and pass the phase of prototypes.
- Implementing new IT and telecommunication technologies is already changing the work process in all the social segments, including the construction people. Today's forms of work were unimaginable only a few years ago.
- Adaptation of commercial structures and globalisation of the market introduces a high level of competitiveness in today's construction section. This means companies need to adopt more efficient and automated means.

Integration

This is a key issue that need to be united, being "from architect's desk to site robots". Three actions should be taken into account for this purpose.

- Erection, transportation and different phases of development procedures, considering prefabrication, assembly, acquiring feedback for the designs.
- Assorted qualities of the plan utilising the most elevated number of the comparable standard pre-assembled components, regarding building diverse houses with similar parts.
- Programming institutionalisation which allow the simple and quick information trade between professionals.

Presentation of automation, and even mechanical autonomy, into the construction cycle to enhance performance, require cautious supervision of dangers and commercial imperative needs to be comprehended by the client or his expert

(professional) advisor at an early stage in the planning procedure (Cusack, 1994; Tambi et al. 2014; Momin, et al. 2015).

Prefabrication

According to Vähä et al. (2013), prefabrication can be described as the practice of assembling and collecting parts of a structure in a plant or other assembling site, and transporting whole assemblies or sub-assemblies to the development site where the structure is to be situated. The term "prefabrication" is utilised to differentiate it from the more ordinary construction routine of transporting essential parts and materials to the site where component manufacture and assembly are done. Expanding this technology would mean covering other materials either than concrete (including composites), and by so it should boost productivity.

According to Kim, et al (2015) as well as Momin, et al. (2015), needed actions may include the following;

- Large scale manufacturing using prefabrication in order to choose the parts from a catalogue. This means a Computer Integrated Manufacturing (CIM) concept must be introduced, including Just in Time (JIT) production.
- Standardisation of the maximum number of parts through the use of grid dimensions, common joints, and connections.
- New materials for prefabricated parts which make them lighter, maintaining the same mechanical features.

Vähä et al. (2012) further stated that automation relating to the prefab construction sector typically falls into one of the three categories:

- The prefab segments making process, (parts, panels, pre-cast, formwork) which manages the development of the building pieces;
- The assembly procedure, in which the building segments are installed to create buildings, houses or structures, by a range of sub-contractors.
- The building business procedures that characterises both the support and business procedures.

Robotics and automated machine

According to Struková and Líska (2013), a range of automation and mechanical autonomy applications in construction robots and automation include three groups: improvement to current building plants and equipment's, task specific machines, and intelligent or cognitive technologies. Improvement to current building plants and equipment's can be acknowledged through the connection of sensors and navigational guides, to give enhanced input to the operator (Mistri et al. 2015; Ruggerio, et al. 2016). As soon as the machine positioned in front of the working area, excavating and setting of soil should be done consequently through sensors and controls added to allow program-controlled operation. Laser controls and ultrasound is commonly used. Task specific, dedicated robots, mostly developed in Japan, usually work under tele-operation or program control. The robots perform well defined tasks, they are normally utilised within a particular area of the building procedure. There are several examples in these categories: machines for structural work (concrete work, steelwork positioning and lifting), machines for finishing work (external spraying of walls, wall

or ceiling panel handling and positioning) and machines for maintenance work (window and floor cleaning).

Intelligent machines present the least developed category, most are still under research. Other applications include the Computer Aided Design/Manufacturing (CAD/CAM) technologies, which its application is not only restricted to the design stage but is connected to and supports application in different stages of development (Tambi et al 2014; Momin, et al. 2015). This is also observed where the advancements have been extended to comprise different functions such as project management, planning and scheduling.

Generally, the importance of computer-aided design and assembling systems comprises of three parts: a digital interactive design and investigation environment for making computerised geometric models of the object to be ultimately produced; a computer-aided manufacturing programme wherein the operator stipulates how the computerised design model is to be really made and makes a series of digital instructions for controlling certain machines; and one or more CNC machines and related tools that interpret these digital commands into actual machines operations that make the object (Mahbub, 2012).

The use of machines and highly automated robots is the key issue, since the utilisation of these guarantees high level of efficiency. Part of the main functions are:

- Robots that are easy to utilise. Create durable robots which are anything but difficult to control and program through friendly human machines interfaces.
- Creating cheap robots which cover single type of use, being not general. This allows the increase of sales of the units.
- Increasing the level of automation of machinery that already exists. Adjust the predictable building machines (cranes, compactors, etc) keeping in mind the end goal to change them into robotic/automated systems.

Investments in research and development

More research and created interest in R&C, in essential and applied research through national and universal focused programs, for example EU research frameworks. One of the key objectives has to be targeted also at changing the culture of the operators directly involved in the building procedure, through education and training. Generally, the operators would oppose the introduction of innovation.

There are other factors that are necessary in incorporating automation for construction activities (Tambi et al, 2014; Kim et al. 2015; Mistri and Rathod, 2015; Ruggiero, et al. 2016), they include such things as selecting important applications, economic feasibility studies, prototype development and field testing, conceptual designs, lab testing, pathfinder development, site implementation, training and lastly manufacturing.

RESEARCH METHODOLOGY

Survey design was adopted for this study through the distribution of questionnaire to construction professionals working with construction and consulting firms in Gauteng region of South Africa. These include project managers, quantity surveyors, architects and construction managers. Purposive sampling was adopted by ensuring that

respondents have adequate knowledge of automation and robotics as well as good knowledge of the construction industry.

The questionnaire was designed in two parts: the first address necessary background information while the main part was designed to obtain information from respondents on the drivers of automation in the construction industry. Identified influences from literature were highlighted in a table and 5-point Likert scale was adopted to seek the opinions of respondents. Cronbach alpha value of 0.907 computed for the eighteen identified factors indicate that the adopted instrument and scale were satisfactory in measuring the opinions of respondents. Mean item score (MIS) and standard deviation (SD) were further calculated for each of the identified variables based on the adopted Likert scale, this was used to rank and determine the level of importance of the factors.

FINDINGS AND DISCUSSION

Table 1 shows various factors influencing the adoption pf automation in the South African construction industry. A 5-point Likert scale of Strongly Disagree – Strong Agree was used for this question and from the results that were gathered, training and site implementation of automation was deemed the most important factor (MIS=4.03, SD=0.800, R=1). In addition, the results showed that a change of attitude in construction companies (MIS=4.00, SD=0.877, R=2), implementation of new IT and telecommunication technologies (MIS=3.78, SD=0.800, R=3) and manufacturing modular components (MIS=3.75, SD=1.006, R=4) were ranked amongst the top four drivers of CA in the South African construction industry. Other important drivers include such activities as increasing the level of existing machinery (MIS=3.65, SD=0.921, R=7), mass production using prefabrication (MIS=3.65, SD=0,700, R=8), prototype development and field testing (MIS=3.65, SD=0.700, R=8) and prefabrication of building components (MIS=3.63, SD=0.925, R=9). Furthermore, areas such as integration of information during the construction process (MIS=3.50, SD=0.784, R=12), pathfinder development and lab testing (MIS=3.48, SD=0.933, R=13), economic feasibility studies (MIS=3.45, SD=1.011, R=14) and conceptual designs (MIS=3.43, SD=0.874, R=15) were ranked as the least set of factors that would aid the adaptation of CA in the South African construction industry.

Table 1: Drivers of automation in the South African construction industry.

Drivers	MIS	SD	R
Training and site implementation of automation	4.03	0.800	1
Change of attitude in construction companies	4.00	0.877	2
Implementation of new IT and telecommunication technologies	3.78	0.800	3
Manufacturing modular components	3.75	1.006	4
Frequent use of robots and automated machines	3.73	0.784	5
Urge companies to adopt more automated and efficient means	3.73	0.751	5
Investments in research and development	3.68	0.888	6
Increasing the level of existing machinery	3.65	0.921	7
Mass production using prefabrication	3.65	0.700	8
Prototype development and field testing	3.65	0.700	8
Prefabrication of building components	3.63	0.925	9
Using easy to use robots	3.58	0.874	10

Selecting important applications to be automated	3.55	0.932	11
Globalisation of the market	3.50	0.716	12
Integration of information during the construction process	3.50	0.784	12
Pathfinder development and lab testing	3.48	0.933	13
Economic feasibility studies	3.45	1.011	14
Conceptual Designs	3.43	0.874	15

MIS=Mean Item Score, SD=Standard Deviation, R=Rank

Table 2 shows the comparison between respondents in contracting and consulting business on the factors influencing CA in the South African construction industry. A 5-point Likert scale of Strongly Disagree – Strongly Agree was used and from the results that were gathered, the professionals in contracting firms ranked the top five factors as increasing the level of existing machinery, implementation of new IT and telecommunication technologies, change of attitude in construction companies, training and site implementation of automation and selecting important applications to be automated. Results from the professionals in consulting firms show that the top five ranked factors are training and site implementation of automation, change of attitude in construction companies, urging companies to adopt more automated and efficient means, frequent use of robots and automated machines as well as manufacturing modular components.

Table 2: Opinions of groups of professionals on drivers of automation in construction.

Factors	Contracting			Consulting		
	MIS	SD	R	MIS	SD	R
Increasing the level of existing machinery	4.18	0.883	1	3.30	0.822	10
Implementation of new IT and telecommunication technologies	4.18	0.883	1	3.48	0.593	6
Change of attitude in construction companies	4.12	1.166	2	3.91	0.596	2
Training and site implementation of automation	4.12	0.857	2	3.96	0.767	1
Selecting important applications to be automated	4.06	0.748	3	3.17	0.887	13
Investments in research and development	4.00	0.866	4	3.35	0.775	9
Prefabrication of building components	4.00	0.935	4	3.39	0.783	8
Manufacturing modular components	3.88	0.993	5	3.61	0.988	4
Frequent use of robots and automated machines	3.88	0.781	5	3.61	0.783	4
Mass production using prefabrication	3.88	0.600	5	3.48	0.730	6
Integration of information during the construction process	3.88	0.697	5	3.22	0.736	12
Prototype development and field testing	3.82	0.809	6	3.57	0.662	5
Urge companies to adopt more automated and efficient means	3.76	1.033	7	3.70	0.470	3
Globalisation of the market	3.71	0.686	8	3.35	0.714	9
Economic feasibility studies	3.71	1.047	8	3.26	0.964	11
Using easy to use robots	3.71	0.985	8	3.48	0.790	6
Conceptual Designs	3.59	1.004	9	3.35	0.775	9
Pathfinder development and lab testing	3.47	1.007	10	3.43	0.843	7

MIS=Mean Item Score, SD=Standard Deviation, R=Rank

Based on the ranking using the calculated MIS and the SD for the listed adaptation factors for CA in the South African construction industry. The results revealed that the dominant factors were; training and site implementation of automation, change of attitude in construction companies, implementation of new IT and telecommunication technologies, manufacturing modular components, and the frequent use of robots and automated machines. Balaguer and Abderrahim (2012) as well as Mistri and Rathod (2016) in their study, mentioned that companies need to change their attitudes and the implementation of new IT and telecommunication technologies which means the findings are in agreement.

Furthermore, using the calculated MIS and SD the results show that the contractors ranked the top five factors as increasing the level of existing machinery, implementation of new IT and telecommunication technologies, change of attitude in construction companies, training and site implementation of automation and selecting important applications to be automated. This is in line with the findings by Momin, et al (2015) and Tambi et al (2014). Results from the professionals show that the top five ranked factors are training and site implementation of automation, change of attitude in construction companies, urge companies to adopt more automated and efficient means, frequent use of robots and automated machines and manufacturing modular components.

CONCLUSION AND RECOMMENDATION

The adoption of fully automated system in the construction industry has various advantages for the level of productivity of workers as well as overall performance of construction projects. The findings from the study show that the top ten factors that need to be taken into account for the adaptation of CA in the South African construction are as follows: training and site implementation of automation, change of attitude in construction companies, implementation of new IT and telecommunication technologies, manufacturing modular components, frequent use of robots and automated machines, urge companies to adopt more automated and efficient means, investments in research and development, increasing the level of existing machinery, mass production using prefabrication and the prototype development and field testing.

The findings from the comparison between the contractors and professionals regarding factors that need to be taken into account for the adaptation of CA in the South Africa construction industry reveal that the contractors ranked the top five as: increasing the level of existing machinery, implementation of new IT and telecommunication technologies, change of attitude in construction companies, training and site implementation of automation and selecting important applications to be automated. The professionals revealed the top five factors as training and site implementation, change in attitude in construction companies, urge companies to adopt more automated and efficient means, frequent use of robots and automated machines and manufacturing modular components. It is therefore necessary for stakeholders in the construction industry to give attention to various identified drivers of automation in the quest of promoting the concept among clients and contractors. This is a view to ensure optimum use of resources for improved project performance.

The focus of this study are various drivers for general automation of construction activities. Further research can be focused on a form of automation such as building information modelling (BIM), CAD/CAM system, standardisation and prefabrication

among others. Specific construction activities, processes or types such as residential, building, road, etc. can also be focused for a direct and better understanding of various drivers of automation.

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